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LIGHT AIRCRAFT SOUND TRANSMISSION STUDY

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CONTENTS

1. Introduction

The plausibility of using the two-microphone sound intensity technique to study noise transmission into light aircraft was investigated. In addition, a simple model to predict the interior sound pressure level of the cabin was constructed. The material presented in this report is a summary of the information in ref. [1]. Background material concerning this topic can be found in refs. [2,3].

2. Transmission Loss Studies in a Direct Field

The structure used in this report was a small, single-engine, non-pressurized fuselage as seen in Figure 1. The starboard side of the fuselage was divided into 4 areas for study - two single-layer plexiglass windows and two aluminum panels with trim. The transmitted sound intensities were measured by sweeping the microphone array as close as possible over the panels of interest. To estimate the transmission loss (TL), the incident as well as the transmitted intensities were needed. For this purpose a string grid, shown in Figure 2, outlined areas equal in size and position with respect to the source as those areas for which the transmitted intensities were measured. The transmission losses of the areas were measured under normal and oblique angles of incidence of the exterior sound field. Transmission losses of the windows were compared to the theoretical mass law TL, shown in Figures 3 and 4. The curves agreed well above 700 Hz. Below this frequency, one would not expect panels of this size and density to follow the mass law. For this reason, the measured TL was assumed to be fairly accurate. These tests were performed while the interior was reasonably anechoic and the assumed major flanking paths were significantly attenuated.

Next the effects of flanking paths were studied. For these measurements the transmission loss of a specific panel was measured without and with the major flanking paths covered. Sample results are shown in Figures 5 and 6. The noise transmitted through the flanking paths seemed to be greatest above 800 Hz.

Later researchers have found the effects of flanking noise to be significant at the higher frequencies, however, not to the large extent presented in this report. As would be expected, sources having high transmitted sound intensities were less affected by the uncovering of flanking paths. Of interest to the small airplane manufacturer is that flanking errors in the 100 to 1000 Hz range are very small. Thus for propeller noise transmitted to the cabin interior, flanking paths should not be a primary concern when acquiring data.

The final section on the study of TL was concerned with the amount of interior absorption. Changing the amount of absorption seems to affect the estimation of the transmission loss in the entire frequency range. Results for the back passenger window are shown in Figure 7.

3. Transmission Loss and SPL Predictions in Reverberant Field

The transmission of sound by the fuselage was then studied in a reverberant exterior sound field. The trends in TL for the four panels, as seen in Figure 8, agreed with those in a direct field. Below 400 Hz the windows and aluminum panels with trim have transmission losses of the same magnitude. Above this frequency, the aluminum panels with trim transmit considerably less sound intensity than the plexiglass windows. In addition the effect on the transmission loss of adding mass to the windows was investigated and shown in Figure 9. Even in the low frequency range, the TL was greatly increased. A simple model based on the room equation was used to predict the space averaged interior SPL in one-third octave bands. This model is more fully described in refs. [1,4]. A space-averaged interior SPL was achieved by rotating a microphone on a boom as shown in Figure 10. The prediction model was good below 400 Hz. However, from theory and previous experience one would expect the model to predict better above 400 Hz where the cabin interior contains many acoustic modes. For this reason, the accuracy of the prediction model may more reliably predict the change in interior SPL due to a modification of the fuselage shell. The change in SPL was predicted to within 1.5 dB up to 500 Hz when covering the windows with leaded-vinyl as seen in Table 1. Leaks were thought to be one of the major causes for the discrepancy at the higher frequencies.

4. SPL Predictions in Direct Sound Field

In order to better control leaks, the fuselage was returned to the semi-anechoic chamber. The prediction model considerably underestimated the interior SPL over the entire frequency range. However, the change in interior SPL from adding leaded-vinyl to a window was predicted up to 800 Hz to within 1.0 dB as shown in Table 2. Of special interest is that the values for additional attenuation from 125 to 400 Hz were predicted very well.

5. Conclusions

As with many measurement processes, the acquisition of data is more difficult than originally hoped. For the two-microphone sound intensity technique, the amount of absorption in the receiving space seems very important. Although the prediction model should not be used to reliably predict the interior SPL, the model does predict the change in interior SPL due to fuselage modifications well. The prediction model is simple to use on any type of computer or programmable calculator. For this reason, quick calculations can be performed to estimate the change in cabin SPL due to a reduction in transmitted power.

6. References

[1] Heitman, K.E., "Investigation of the Noise Transmission into a Light Aircraft Cabin Using the Two-Microphone Sound Intensity Technique," MSME Thesis, Purdue University, December 1983.

[2] Forssen, B.H., "Determination of Transmission Loss, Acoustic Velocity, Surface Velocity and Radiation Efficiency by Use of Two Microphone Technique," Ph.D. Thesis, Purdue University, August 1983.

[3] Wang, Y.S., "Transmission of Sound Through a Cylindrical Shell and a Light Aircraft Fuselage," Ph.D. Thesis, Purdue University, December 1983.

[4] Atwal, M.; David, J.; Heitman, K.; Crocker, M., "Light Aircraft Sound Transmission Study," Herrick Laboratories Report HL 83-21, August 1983.

TABLE 1

Change in Interior SPL Due to the Addition of Leaded-Vinyl Over the Windows in a Reverberant Field

One-Third Octave Center Frequency, Hz	Measured Values dB	Predicted Values dB
100	2.51	3.21
125	0.44	2.38
160	0.64	1.33
200	1.37	1.40
250	1.09	2.47
315	0.84	1.37
400	1.82	2.20
500	2.32	3.69
630	1.90	4.62
800	-0.23	4.39
1000	-0.46	4.13

TABLE 2

Change in Interior SPL Due to the Addition of Leaded-Vinyl Over the Window in a Direct Field

One-Third Octave Center Frequency, Hz	Measured Values dB	Predicted Values dB
100	4.23	4.84
125	1.23	2.68
160	0.11	0.80
200	0.51	0.64
250	0.61	0.74
315	0.68	1.62
400	2.54	2.06
500	3.28	3.88
630	3.03	3.12
800	2.34	1.35
1000	-0.48	1.17

Figure 1 Photograph of fuselage in semi-anechoic chamber.

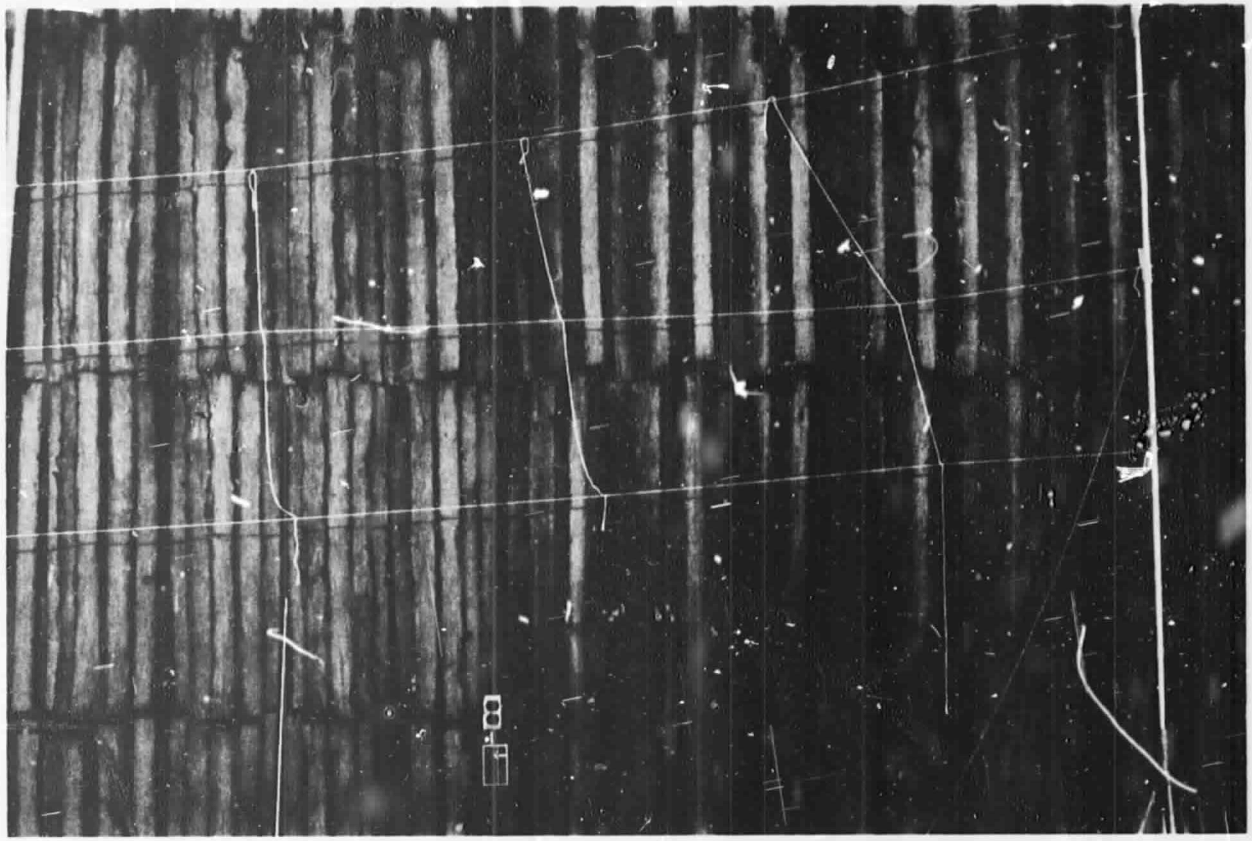

Figure 2 Photograph of string grid used to measure the incident intensities.

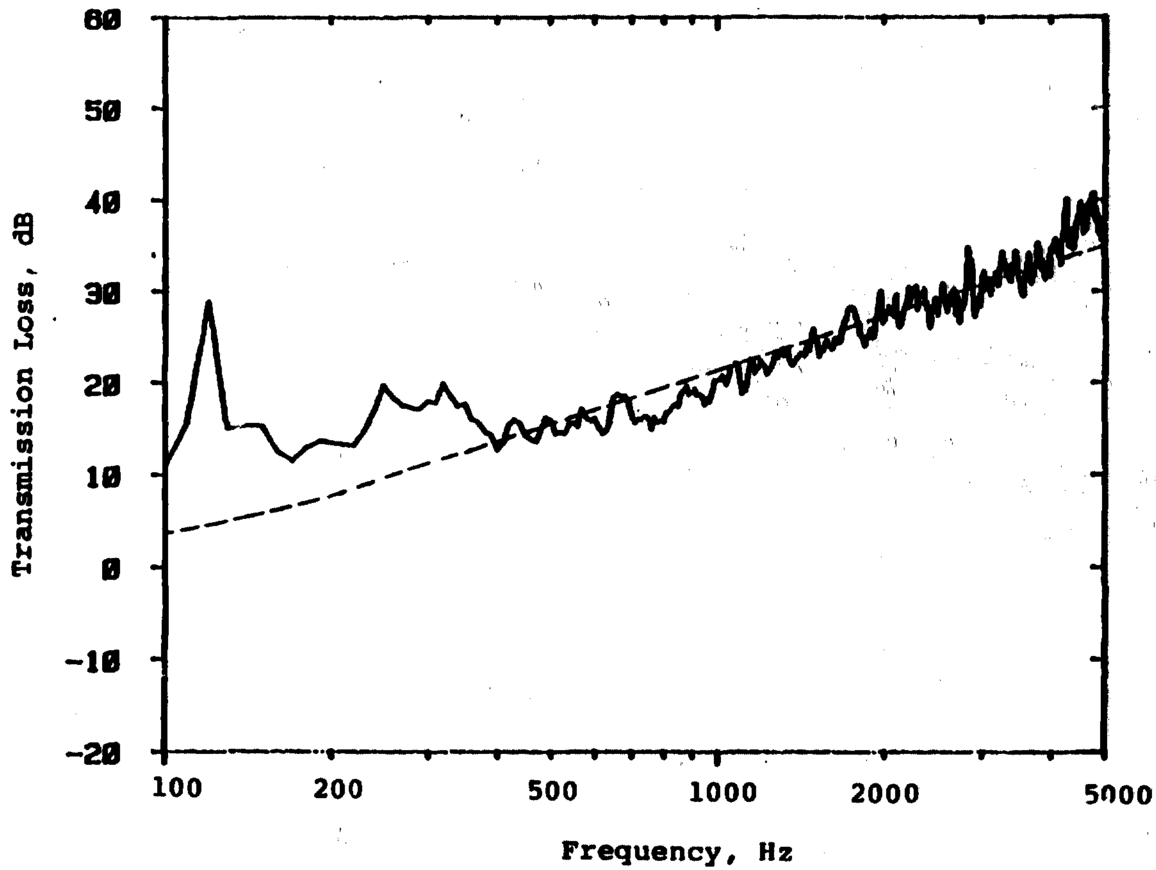

Figure 3 Transmission loss vs. frequency for the back passenger window at normal incidence (O=0). ——— experimental data, — — —theoretical mass law.

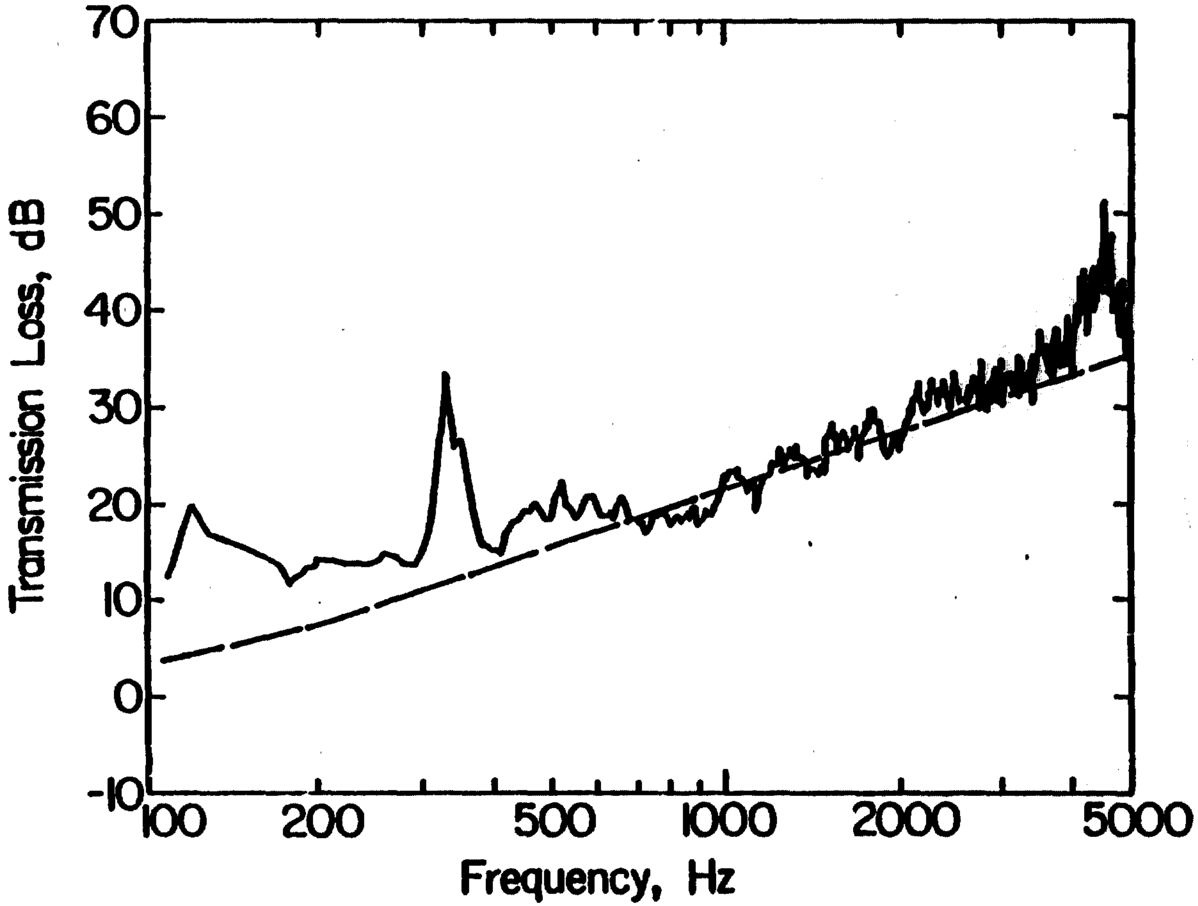

Figure 4 Transmission loss vs. frequency for the door window at normal incidence. ——— experimental data, – – – theoretical mass law.

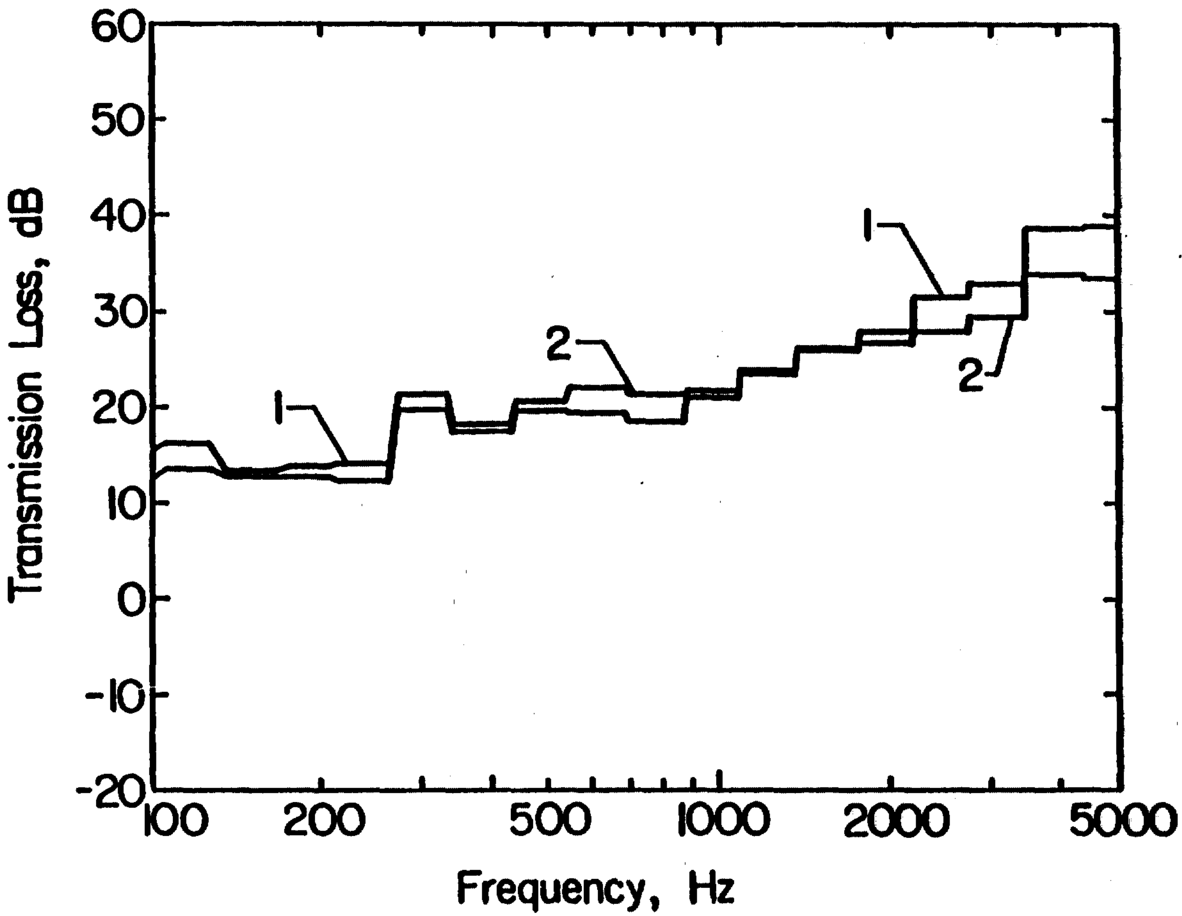

Figure 5 The effect of flanking noise on the door window transmission loss vs. frequency for normal incidence. (1) Blocked flanking paths, (2) Unblocked flanking paths.

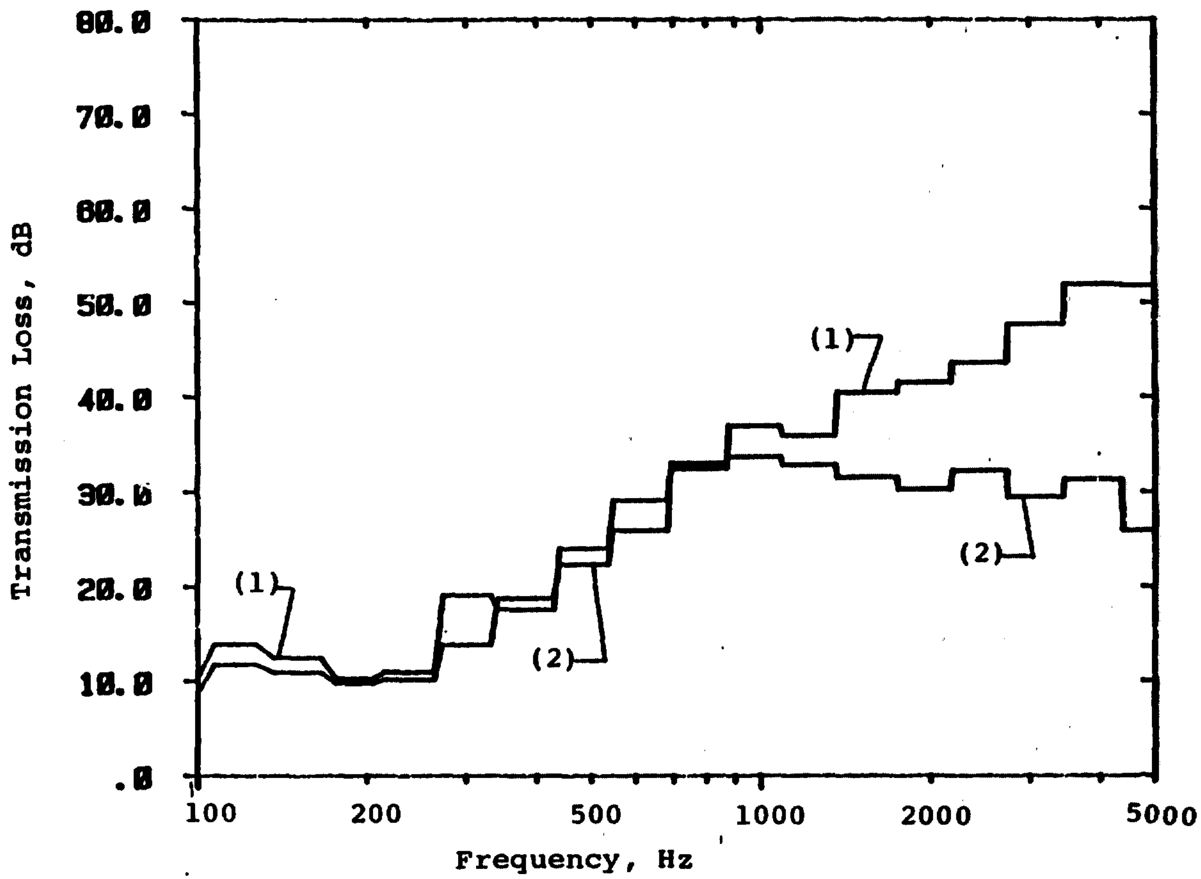

Figure 6 The effect of flanking noise on the back passenger panel transmission loss vs. frequency for oblique incidence. (1) Blocked flanking paths, (2) Unblocked flanking paths.

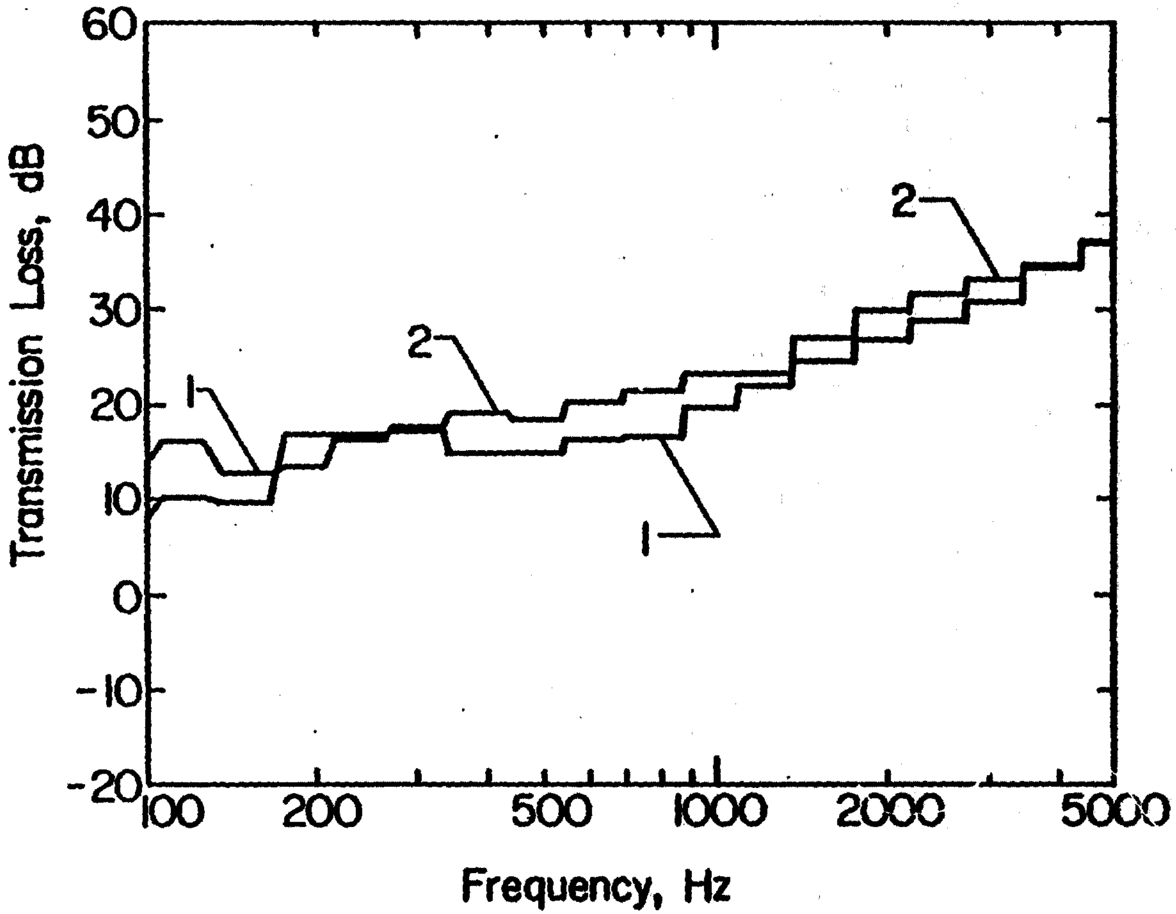

Figure 7   Transmission loss of the back passenger window for normal incidence. (1) Anechoic interior, (2) Non-anechoic interior.

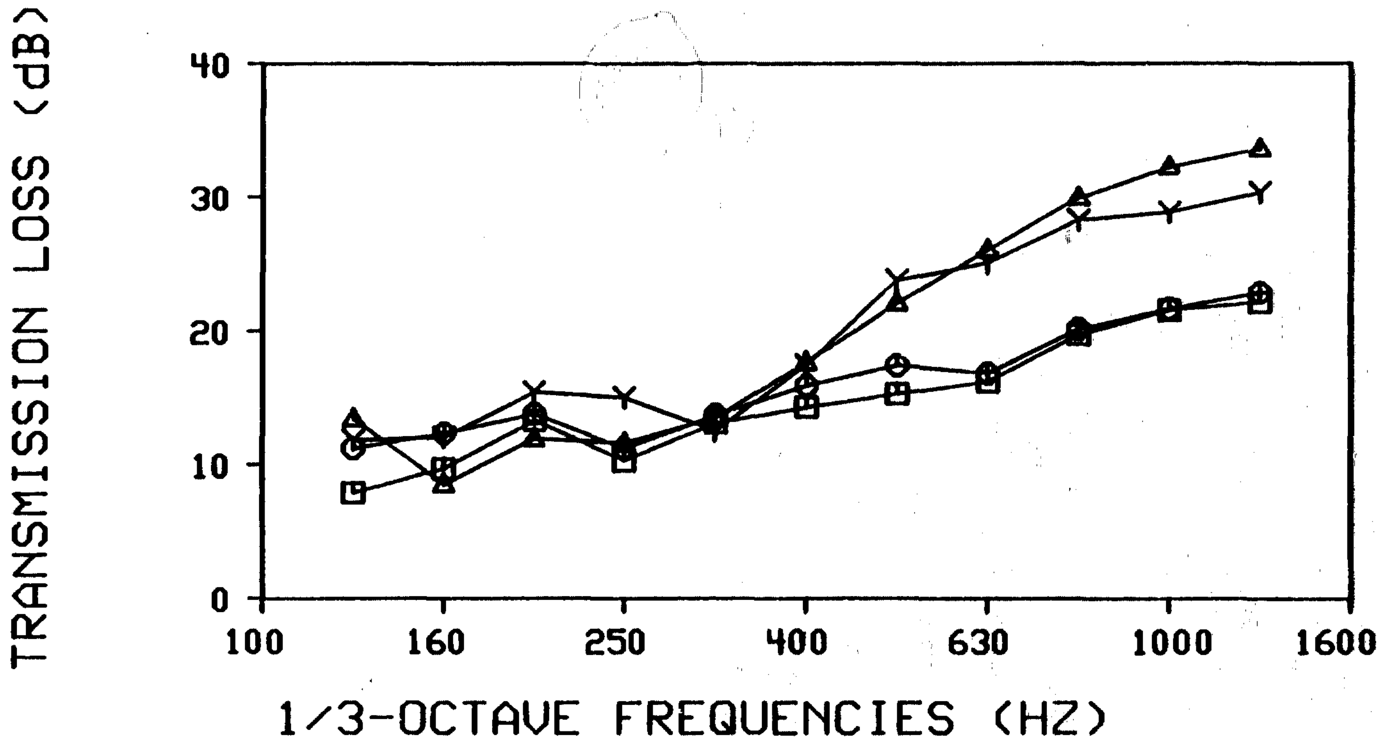

Figure 8 Transmission loss as a function of frequency for a reverberant exterior sound field. (□—□)-back passenger window, (○—○)-door window, (△—△)-back passenger aluminum panel, (Y—Y)-door aluminum panel.

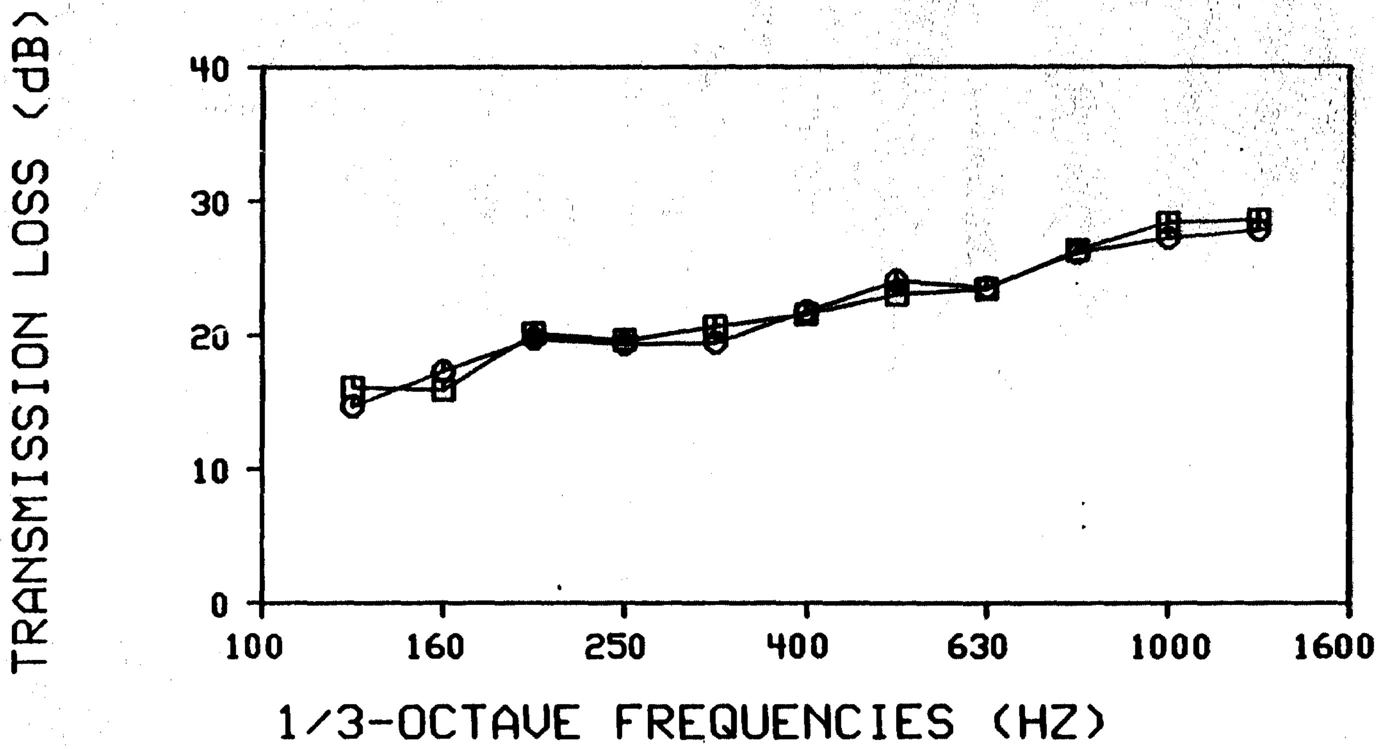

Figure 9 Transmission loss as a function of frequency for a reverberant exterior sound field. Plexiglass windows are covered with one sheet of leaded-vinyl. (□—□)-back passenger window, (○—○)-door window.

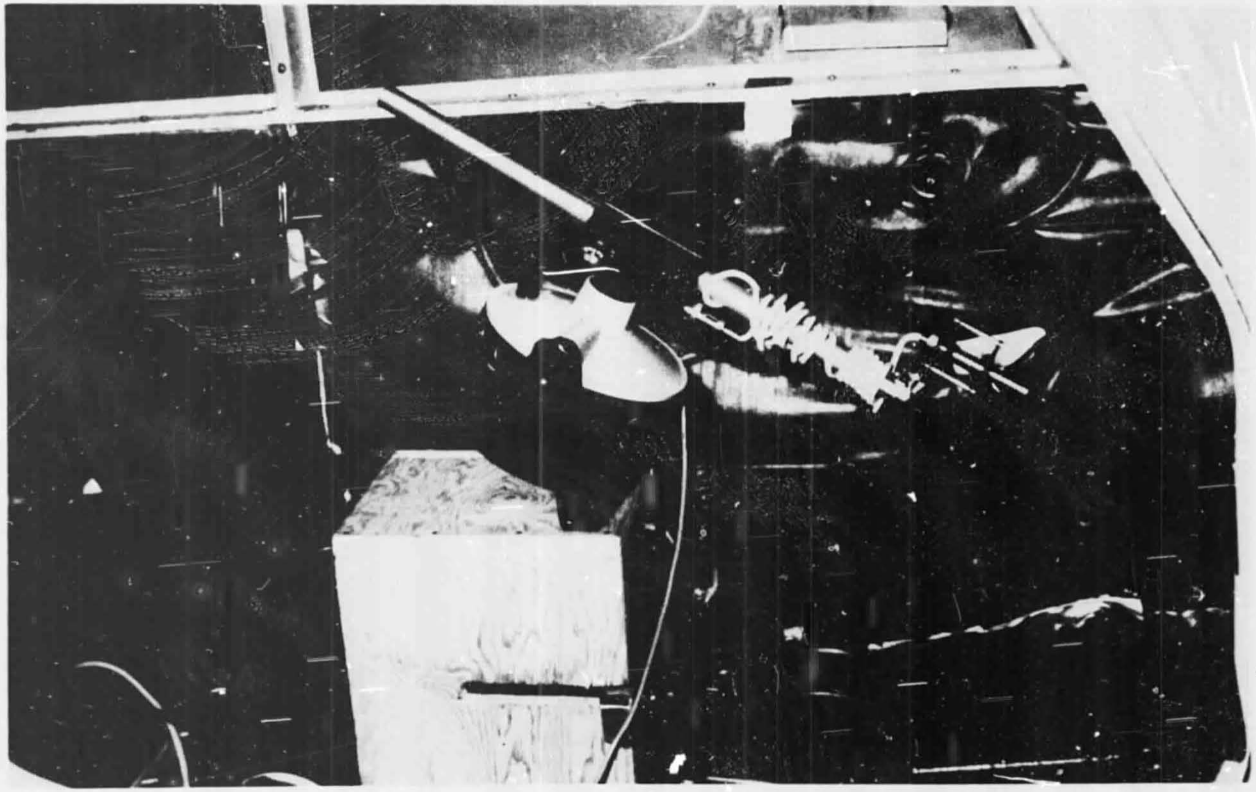

Figure 10 Photograph of microphone apparatus used to measure the space-averaged interior sound pressure level.